RUSSIAN OLIVE (*Elaeagnus angustifolius*): Russian olive is a cultivated shrub or tree, native to temperate Asia. It is not yet a significant problem but can become one if not controlled. It is planted in landscaping and has been planted extensively in wind breaks. It spreads into riparian areas from seed and at maturity, crowds out native species.

PERENNIAL PEPPERWEED (*Lepidium latifolium*): Perennial pepperweed is a mustard family plant, native to Eurasia, that is widespread in the United States. It was introduced to North America in the early 1800s and reportedly first introduced to Yolo County as a contaminant of sugar beet seed (Young et al. 1996). It is found in all counties in the ERPP study area. It infests freshwater riparian and wetland areas and salt-affected areas, including coastal salt marshes, often where there was past disturbance. It can also grow in areas that are only seasonally wet. The plants grow fast, up to two or more meters tall, and spread both by rhizomes and seeds, forming dense stands that exclude all other vegetation. Once stems begin growing, most herbivores will not eat the plants (Young et al. 1996). An example of a perennial pepperweed infestation may be found at Grizzly Island in the Delta.

GERMAN IVY (*Senecio milkanioides*): This vine, native to South Africa, has been planted horticulturally and has spread into primarily coastal riparian forests. German ivy can be found in Marin and Sonoma County riparian forests. It carpets large expanses of forest understory and climbs to the canopy of willow and cottonwood trees. Competing for nutrients and water and preventing sunlight from reaching seedlings, it reduces the cover of native vegetation and the riparian community structure.

CORDGRASS (*Spartina alterniflora, S. anglica, S. densiflora, S. patens*): *Spartina alterniflora*, native to eastern North America; *S. anglica, S. densiflora,* native to South America; and *S. patens*, native to the southeastern United States were intentionally introduced to San Francisco Bay areas in the 1970s (Callaway and Josselyn 1992, Daehler and Strong 1994, Spicher and Josselyn 1985, Spicher 1984). All introduced cordgrasses are a threat to the open intertidal mud and salt marsh communities in estuarine areas. The cordgrasses form tall, dense colonies in the mud with thick root systems. The result is alteration of tidal flows and increased sedimentation, as well as displacement of clams, worms, crustaceans, and shorebirds that depend on these prey species. An additional threat is to the native *S. foliosa*, which becomes overgrown by *S. alterniflora* (Callaway and Josselyn 1992) and can hybridize with it (Strong and Daehler 1996). The native *S. foliosa* community provides habitats for the clapper rail and salt marsh harvest mouse.

PURPLE LOOSESTRIFE (*Lythrum salicaria*): Native to Eurasia, this riparian herbaceous weed was introduced to North America in the early 1800s and has since invaded wetlands throughout the United States. It forms large monotypic stands, displacing native species, and can eliminate shallow open-water areas otherwise used by waterfowl and wildlife.

ISSUES AND OPPORTUNITIES

INTRODUCED SPECIES: Introduced species have had a significant impact throughout the Bay-Delta ecosystem, and they can pose a significant impediment to achieving restoration objectives. In order to minimize the risk of potentially massive ecological and biological disruptions associated with non-native species-disruptions that could threaten to negate the benefits of restoration efforts-it is important to initiate an early program that:

- prevents or significantly reduces additional introductions of non-native species,
- develops a better understanding of how non-native species affect ecological processes and biological interactions,
- develops effective control and eradication programs, and
- establishes habitat conditions that favor native over non-native species (Strategic Plan 2000).

OPPORTUNITIES: Reduce or eradicate invasive non-native shrubs and trees from riparian corridors. Of particular importance is the control of the spread of tamarisk and giant reed, two introduced species that displace native flora, offer marginal value to fish and wildlife, and cause channel instability and reduced floodway capacity. Some rivers, such as Stony Creek and Cache Creek and the lower San Joaquin River, have undergone large expansions of these non-native species, even in the past 10-15 years. A combination of large-scale eradication pilot projects and targeted research on several streams will help to temporarily reduce the rate of expansion of their range, identify the most vulnerable stream

environments, and determine whether valley-wide eradication or suppression measures are warranted or feasible (Strategic Plan 2000).

VISION

The vision for invasive riparian and salt marsh plant species is to reduce their adverse effects on native species and ecological processes, water quality and water conveyance systems, and major rivers and their tributaries.

Active management is necessary to reduce invasive plant populations that compete with the establishment and succession of native riparian vegetation in the Delta and Sacramento and San Joaquin Rivers and their tributaries in order to:

- assist in the natural reestablishment of native riparian vegetation in floodplains,
- increase shaded riverine cover for fish,
- reduce stress on rare species and communities, and
- increase habitat values for riparian associated wildlife.

Reduction of populations of invasive plant species that compete with the establishment and succession of native saline and fresh emergent marsh vegetation would also assist in the natural reestablishment of these native habitats and increase habitat values for associated wildlife. Developing and enhancing programs that protect and restore our State's natural resources and biological diversity while fulfilling our flood control, water conveyance, and compatible economic development needs are necessary if efforts are to succeed on a long-term basis. Historically, governmental weed control programs have been aimed at non-native species, which has adversely affected commerce, primarily agriculture, or public services such as water delivery. Weeds in natural areas have historically not been addressed but are now areas of great and increasing concern. Expanding existing governmental and private programs or creating new, similar programs is needed to perpetually monitor, research, and control weeds that impact natural areas, and to prevent new infestations by existing weeds or new introductions. To minimize recurring infestations, programs to actively restore native habitats will require expansion into areas where infestations have been removed.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

The California Department of Food and Agriculture's Integrated Pest Control Branch has responsibility for tracking and controlling federally listed noxious weeds statewide. These are weeds that have an impact on agriculture, although most of the current infestations are restricted to natural and uncultivated areas (O'Connell pers. comm.). Listed weeds are given an "A", "B", or "C" designation. "A" weeds are tracked and targeted for control or eradication wherever they are found. "B" weeds are considered too widespread to require mandated control measures; the choice for controlling them is left to the county agricultural commissioners. "C"-rated weeds are so widespread that the agency does not endorse State- or county-funded eradication or control efforts except in nurseries and seed lots. Of the weeds described in this vision statement, only perennial pepperweed and purple loosestrife are listed as noxious agricultural weeds, both with a "B" designation. With funding, the California Department of Food and Agriculture's Integrated Pest Control Branch could be expanded to include weeds adversely affecting natural areas and their existing infrastructure and expertise used to track, map, and control weeds that are problems in natural areas.

Two recently announced programs or policy changes may bear positively on the vision for controlling aquatic, riparian, and salt marsh weeds. The first is that the U.S. Department of Animal and Plant Health Inspection Service (APHIS) developed a new weed policy that includes regulation of all types of weeds, including not only those threatening agricultural or managed areas, but natural area weeds as well. The program will use a risk assessment to list and delist noxious weeds. Among other aspects of the new policy, APHIS will institute a regulatory role of detecting, assessing, and containing incipient infestations. The policy states that APHIS will play a federal coordination role to facilitate communication and cooperation between relevant public agencies and others.

The second new approach was formed through a Memorandum of Understanding (MOU) signed by 17 land-holding federal agencies in 1994. A committee was formed called the Federal Interagency

Committee for Management of Noxious and Exotic Weeds. The purpose of the MOU and committee formation is to enable the signing agencies to cooperatively manage noxious and non-native weeds on federal lands and to provide technical assistance on private land to achieve the goal of sustainable, healthy ecosystems that meet the needs of society.

The Delta Flood Protection Program (AB 369) has data on the location and extent of invasive plants associated by levees in the Delta. The program has "habitat assistance" describing the kinds and extent of plants on the levees; Arundo is particularly noted. The eradication of Arundo by levee districts is considered as a beneficial habitat change and is reimbursable by the program.

There are many other organizations with an interest in weed issues in the ERPP study area. All have different roles, interests, and expertise. To attain ERPP's goals, a coordinated effort would be needed among the groups to develop, prioritize, and implement weed management programs and strategies that will help to achieve ecological zone and resource visions.

- The University of California Weed Science Program in the Vegetable Crops Department conducts ongoing research on weed ecology and control, including non-crop and natural area problems.
- The California Exotic Pest Plant Council is a nonprofit organization that focuses on issues regarding non-native pest plants and their control, and on public education regarding the issues.
- The California Weed Science Society is a 50-year-old organization serving the weed science community.
- The U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and the California Department of Fish and Game have regulatory roles pertaining to weed control.

Several public and private groups dealing with weeds directly or indirectly in the ERPP study area can also be included. Among these are:

- the California Native Plant Society,
- The Nature Conservancy,
- State and national parks, county and local parks,
- U.S. Bureau of Land Management,
- APHIS,
- U.S. Army Corps of Engineers,
- U.S. Natural Resource Conservation Service,
- Center for Natural Lands Management,
- resource conservation districts,
- mosquito abatement districts,
- flood control districts,
- California Association of Nurserymen,
- Team Arundo, and Team Arundo del Norte,
- local land trusts,
- and private landowners.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Invasive riparian and salt marsh plants adversely influence other ecosystem elements such as riparian and riverine aquatic habitat, and fish, wildlife, and plant species.

OBJECTIVES, TARGETS, ACTIONS, AND MEASURES

Two Strategic Objectives address invasive riparian and marsh plants.

The first Strategic Objective is to halt the introduction of non-native invasive aquatic and terrestrial plants into the Bay-Delta estuary, its watershed, and other central California waters.

LONG-TERM OBJECTIVE: Halt the importation, sale, and use of aquatic and terrestrial plants that can have potentially harmful impacts on ecosystems in the Bay-Delta watershed.

SHORT-TERM OBJECTIVE: Develop and institute strategies, working with the horticulture industry and interests representing the environment and other sectors that may be affected by such

introductions, to halt the introduction and spread of invasive plant species.

RATIONALE: Many areas of the Central California landscape are dominated by non-native plant species (e.g., annual grasslands, eucalyptus forests) that have displaced native species and have unexpected negative impacts. Parrot's feather, for example, is an ornamental aquatic plant that is now widespread, clogging ponds and ditches in the Bay-Delta watershed, thereby creating breeding habitat for mosquitoes. Many harmful species (e.g., water hyacinth) can easily be purchased in plant nurseries and so continue to be spread into natural systems. New species and varieties of plants from all over the world are constantly being brought into California with little evaluation of their invasive qualities. Some species (e.g., Atlantic and English cordgrass) have even been imported for marsh restoration projects! There clearly is a need to evaluate the plants imported into California from other regions and to better regulate the horticultural industry to make sure potentially invasive plants are not available for spreading by gardeners, landscapers, and people engaged in restoration or reclamation activities. There is also a need to better educate the public on the adverse impacts of invasive species and the need to not to allow garden plants to escape into natural environments.

STAGE 1 EXPECTATIONS: Plants sold in California by the horticulture industry that pose a threat to ecosystems in the Bay-Delta watershed will have been identified and evaluated for invasive potential. Special attention will be paid to plants imported into the region from other areas. Working with the horticulture industry and affected interests, a plan will have been developed and instituted to greatly reduce, and eventually eliminate, the introduction of additional invasive plant species into natural environments.

The second Strategic Objective for invasive riparian and marsh plants is to limit the spread or, when possible and appropriate, eradicate populations of non-native invasive species through focused management efforts.

LONG-TERM OBJECTIVE: Eliminate, or control to a level of little significance, all undesirable non-native species, where feasible.

SHORT-TERM OBJECTIVE: Eradicate or contain those species for which this can readily be done, gaining thereby the largest benefit for the least economic and environmental cost; and to monitor for the arrival of new invasive species and, where feasible, respond quickly to eradicate them.

RATIONALE: Non-native species are now part of most aquatic, riparian, and terrestrial ecosystems in California. In most instances, control is either not possible or not desirable. However, in some instances, control of invasive species is needed to protect the remaining native elements or to support human uses. Four factors should be considered in focusing control efforts. First, an introduced species is often not recognized as a problem by society until it has become widespread and abundant. At that point, control efforts are likely to be difficult, expensive, and relatively ineffective, while producing substantial environmental side effects or risks, including public health risks. Second, some organisms, by nature or circumstance, are more susceptible to control than others. Rooted plants are in general more controllable than mobile animals, and organisms restricted to smaller, isolated water bodies are in general more controllable than organisms free to roam throughout large, hydrologically connected systems. Third, although biological control is conceptually very appealing, it is rarely successful and always carries some risk of unexpected side effects, such as an introduced control agent "controlling" desirable native species. And fourth, physical or chemical control methods used in maintenance control rather than eradication require an indefinite commitment to ongoing environmental disturbance, expense, and possibly public health risks. Overall, the most efficient, cost-effective, and environmentally beneficial control programs may be those that target the most susceptible species, and species that are not yet widespread and abundant. This suggests a need to (1) assess the array of introduced species and focus on those that are most amenable to containment and eradication, rather than focusing just on those that are currently making headlines, and (2) responding rapidly to eradicate new introductions rather than waiting until they spread and become difficult or impossible to eradicate.

An example of a "rare" introduced species needing eradication that is not being dealt with is English cordgrass in the Bay. It has been described by some scientists as the most aggressive and invasive salt marsh plant in the world. It has been in the Bay, its only known California location, for 20 years without spreading, so it has not generated concern. However, in other parts of the world it has also sometimes sat around for a few decades without doing much of anything, then suddenly taken off and taken over entire estuaries in a few years. In San Francisco Bay, it is known from one site only, where it was planted, and where it exists in a single patch. It could readily be eradicated.

STAGE 1 EXPECTATIONS: An assessment will be completed of existing introductions to identify those with the greatest potential for containment or eradication, and consider this in prioritizing control efforts. A program will have been implemented to monitor for, and respond quickly to contain and eradicate new invasions, where this is possible. A mechanism whereby new invasions can be dealt with quickly and effectively will have been developed an implemented.

RESTORATION ACTIONS

The general target for invasive riparian and saltmarsh plants is to prevent them from becoming established in riparian and saltmarsh restoration areas, conduct distribution and abundance surveys throughout the ERPP Study Area, and develop and implement control and eradication programs for high priority problem areas.

A comprehensive strategy to reduce invasive riparian and salt marsh plant populations and their adverse effects on the Bay-Delta ecosystem would include the following items.

- Assess weeds for their levels of a threat, their extent, and their potential for long-term control.
- Assess potential weed control sites for their likelihood to provide the greatest return on control efforts in terms of improved habitat quality and other benefits, such as reducing flood risk and channel instability, longevity of results, and ability to supply the types of habitats and habitat characteristics proposed for restoration.
- Develop and implement management plans based on the assessment of weeds and sites to achieve specific targets for each weed and site.
- Wherever necessary and appropriate, implement habitat restoration simultaneous with or following control measures.
- For arundo and tamarisk, eradicate the weeds in watersheds where they have only small populations, then concentrate on eradicating satellite populations extending beyond major infestations, and finally, reduce and eventually eliminate the most extensive populations.
- Provide technical expertise, serve as a clearinghouse for regional information and project results, and assist with implementing high-priority local projects in specific ecological units or zones to increase the effectiveness of existing public and private programs to reduce the threat of invasive species.

MSCS CONSERVATION MEASURES

The following conservation measures were included in the Multi-Species Conservation Strategy (2000) to provide additional detail to ERP actions that would help achieve species habitat or population targets.

- Identify and implement feasible methods for controlling invasive non-native marsh plants.
- Control non-native invasive plants in existing salt marshes where non-native plants have degraded habitat quality and in salt marshes restored under the ERP.
- Control and reduce populations of non-native marsh species with potential effects on soft bird's-beak and potential soft bird's-beak habitat.

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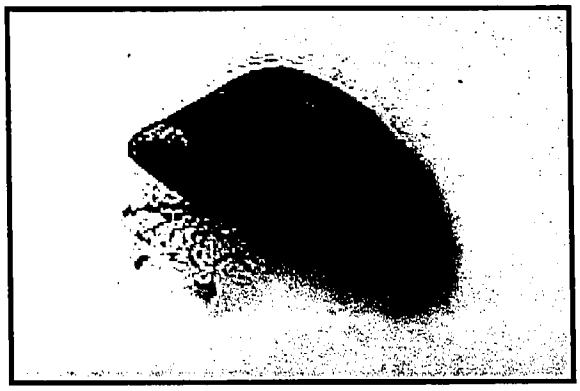
◆ ZEBRA MUSSEL

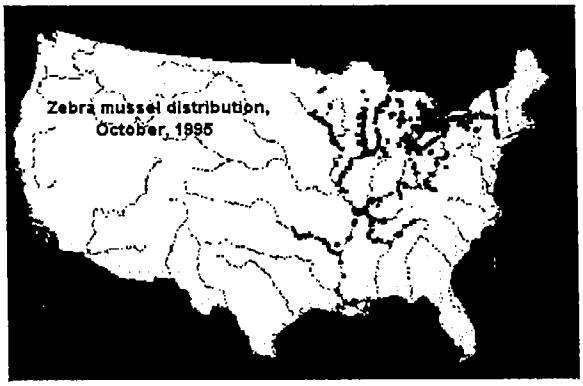


INTRODUCTION

Zebra mussels are a highly invasive exotic bivalve first discovered in the Great Lakes region in 1988 (Hebert et al. 1989). Since its introduction, the zebra mussel has caused widespread disruption of important foodweb processes in the region, altered fish species abundances, and impaired water export facilities used for municipal, industrial, and power generation purposes. The zebra mussel is not known to occur in California at this time. The introduction of zebra mussel into California's Bay-Delta watershed would be an environmental and economic catastrophe.

STRESSOR DESCRIPTION

Zebra mussels are small shellfish marked by alternating light and dark bands. They are typically 2 inches or less in size. Zebra mussels are native to the drainage basins of the Black, Caspian, and Aral seas of Eastern Europe. It is believed that ships originating from European ports carried the pest in freshwater ballast which was discharged into the Great Lakes. The first North American zebra mussel as discovered in Lake St. Clair, Michigan in June 1988. By September 1991, the mussel was found in all five of the Great Lakes, the St. Lawrence River, the Finger Lakes region of New York, and throughout the Mississippi River basin. The mussel is expected to infest most areas of North America within the next few years (New Hampshire Department of Natural Resources 1998).

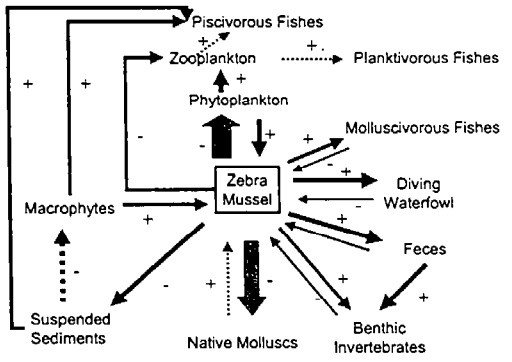


Zebra mussels are the only freshwater mussel which can secrete durable elastic strands, called byssal fibers, by which they can securely attach to nearly any surface, forming barnacle-like encrustations. Through this mechanism zebra mussels can attach to stone, wood, concrete, iron, steel, aluminum, plastic, fiberglass, and PVC. Zebra mussels typically colonize at densities greater than 30,000 individuals per square meter.

The specific origin of zebra mussels introduced into the Great Lakes is unknown but they are widespread throughout western and eastern Europe (Marsden 1996). Zebra mussels have successfully invaded a wide variety of aquatic habitats including freshwater lakes and rivers, cooling ponds, quarries, and irrigation ponds on golf courses (Strayer 1991). Recent information suggests that zebra mussel can invade brackish water or estuaries where salinities do not exceed 8 to 12 ppt.

Water quality factors that limit colonization by zebra mussel appear to include temperature, pH, and calcium content of the ambient water. The upper thermal tolerance is between 68 to 77 °F. Lower limit of calcium is 12 mg per liter and a combined threshold for pH and calcium is 7.1 and 8.5 mg per liter.

Adult zebra mussel tissues have a very high nutrient value and in the Great Lakes region are consumed in large quantities by crayfish, fish, and waterfowl (Mackie and Schloesser 1996).



Schematic of observed (solid line) and potential (dotted line) impacts of zebra mussel in freshwater communities based on European and North American studies. Taxa benefitting from zebra mussel invasion and indicated with a (+) symbol, those adversely affected by a (-) symbol. Strong interactions are denoted by thicker arrows. Zebra mussel may indirectly impact piscivorous and planktivorous fish by altering food supply or habitat quality (Adapted from MacIsaac 1996).

Zebra mussels become sexually mature in their first year of life and, depending on size, can produce 30,000 to 1,610,000 eggs per female.

Zebra mussel disperse by a variety of natural and anthropogenic means. Natural means include flowing water, birds, insects, and other animals. Human-mediated events include artificial waterways, ships, amphibious aircraft, and recreational equipments such as boats and other watercraft (Mackie and Schloesser 1996).

Live mussels have been reported found in Los Angeles attached to trailered boats. The California Department of Water Resources has also reported three more boats brought into the State since June 1996 carried zebra mussels. All three boats came from the Great Lakes region and were headed for saltwater destinations. The first of these three boats was intercepted at the Hornbrook Inspection Station near the Oregon border in June 1997 and the other two were stopped at the Truckee Inspection Station in September and December of 1996. This brought the total number of boats entering California found to be infested with zebra mussel to eleven boats since 1993.

The 1986 invasion of the Great Lakes by zebra mussel provides one of the most instructive examples of ecological modification and economic damage associated with human-mediated species introductions. (Hebert et al. 1989).

The greatest abiotic effect anticipated from an invasion by zebra mussel will be problems associated the mussel biofouling. Permanent marine structures such as pilings, bridges and docks are particularly susceptible of fouling. Water intake structures for municipal, industrial, and agricultural diversions and intake structures for power generation plants are highly vulnerable to fouling or clogging if they divert water from a source contaminated with adult or juvenile zebra mussel. Power plants components that are susceptible to biofouling include crib structures, trash bars, screen houses, steam condensers, heat exchangers, penstocks, and service water systems.

Very long or narrow pipelines are particularly vulnerable to biofouling and severely restricted flows (Claudia, R. and G.L. Mackie 1993). Mussel densities at the Monroe power plant in western Lake Erie have been reported to be as high as 750,000 individuals per square meter. These extraordinary mussel densities can be achieved in raw water intakes because of the enormous number of potential colonists entrained in the intake current, constant replenishment of nutrients and removal of mussel wastes, and absence of predators (MacIsaac 1996).

One of the most predictable outcomes of a zebra mussel invasion and a significant abiotic effect is enhanced water clarity. This also is linked to a greatly diminished phytoplankton biomass. For example, rotifer abundance in western Lake Erie declined by 74% between 1988 and the 1989-1993 period, a time coincident with the establishment of an enormous zebra mussel population beginning in 1989 (Leach 1993).

VISION

The vision for zebra mussel is to establish procedures to prevent or delay their introduction and to set up protocols to swiftly treat and eliminate any introduction.

This includes all appropriate efforts will be maintained to interdict potential sources of zebra mussels at all border check stations and other potential sources of introduction. The vision also includes an emergency response strategy to quickly contain and eradicate any suspected or proven mussel colonies.

This vision is consistent with the visions for other invasive species, particularly for invasive aquatic species and relies on measures to prevent introductions through contaminated ballast water.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

- California Department of Food and Agriculture's border inspection stations.
- Michigan Sea Grant Zebra Mussel/Aquatic Nuisance Species Program which serves as a centralized source of information exchange.
- Fish and Game Commission which can regulates the importation of live animals or aquatic plants.
- California Department of Fish and Game which issues permits for the importation of live animals and aquatic plants.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Invasive aquatic organisms adversely influence other ecosystem elements including ecological processes, habitats, and species. For example, introduced species have out competed and displaced many native species. The proliferation of these exotic organisms has altered the Bay-Delta foodweb.

OBJECTIVE, TARGETS, AND, ACTIONS

The Strategic Objective is to prevent the invasion of the zebra mussel into California.

LONG-TERM OBJECTIVES: Develop an emergency response strategy to quickly contain and eradicate zebra mussels should they arrive in California. Continue to inspect trailered boats at the California border to intercept zebra mussels attached to boats.

SHORT-TERM OBJECTIVES: Coordinate activities with California Department of Food and Agricultural to increase monitoring activities at port of entries (boarder crossings) into California. Develop and fund protocols for inspecting vessels that enter the State from areas where zebra mussels are know to occur. Activities would also need to be under taken with adjoining states to prevent zebra mussels from becoming established in common waterways.

RATIONALE: The zebra mussel has done enormous damage to water supply infrastructure and to natural ecosystems in the eastern United States, through which they are spreading rapidly. It is likely that at some point a live population of zebra mussels will appear in California waters through any one of several means. Studies have already demonstrated that it will likely thrive in many parts of the California water system. Therefore, it is highly desirable to have in place a strategy to deal with a localized invasion, along with a commitment of resources from agencies so that rapid action is possible.

STAGE 1 EXPECTATIONS: A determination should be made as to which waters which are most likely to serve as an initial site of invasion for zebra mussels (taking into account both water quality and other environmental factors and the mechanisms likely to transport zebra mussels); a zebra mussel monitoring program for these waters should be developed; and a rapid response strategy should be developed to contain and eradicate an incipient zebra mussel invasion. In addition, the most likely source for introducing zebra mussels is boats carried by trailer from areas where zebra mussels are abundant. California already has an agricultural inspection program, and this program now includes inspection of boats for mussels.

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